IMMEDIATE GRANT BUS ARBITER FOR BUS SYSTEM

Steve Jahnke

Hiromichi Hamakawa

TECHNICAL FIELD OF THE INVENTION

The technical field of this invention is data transfer and data bus systems within computer systems.

5   ## BACKGROUND OF THE INVENTION

As computer systems have grown more complex, it has become common to employ multiple processors and a wide variety of peripheral devices to transfer data within a chip and from the chip to external devices and vice versa.   Such systems

almost always have a multiple set of busses separating, for convenience and performance reasons, the communication between similar devices.   Multiple bus systems must provide bus controllers to allow for coherent and collision-free
5   communication between separate buses. Micro-controllers are used for this purpose and they provide bus arbitration which determines, at a given time, which device has control of the bus in question.

A prominent standard bus system has emerged for high
10   performance micro-controller designs. The 'Advanced Micro-controller Bus Architecture System' AMBA has been defined by Advanced RISC Machines (ARM) Ltd. (Cambridge, U.K.) and is described in U.S. Patent 5,740,461, dated April 14, 1998. Computer systems of a CISC variety are complex instruction set
15   computers and have total backward compatibility requirements over all versions. RISC (reduced instruction set computer) systems, by contrast, are designed to have simple instruction sets and maximized efficiency of operation. Complex operations are accomplished in RISC machines as well, but they are
20   achieved by using combinations of simple instructions. The RISC machines of ARM Ltd. forming the AMBA architecture are of primary interest here.

The standard AMBA has two main busses, a high performance AHB bus and a peripheral bus APB of more moderate performance.
25   The AHB bus is the main memory bus and contains RAM and an external memory controller. In this basic system definition, if a high performance peripheral is required that will transfer large amounts of data, this peripheral is also placed on the high performance AHB bus.   This decreases system
30   performance, however, because the central processor unit (CPU)

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cannot have access to memory when the peripheral has control
of the bus.

Advanced RISC Machines Ltd (ARM) has proposed an
efficient arbitration scheme and split transfers to allow the
5   CPU and the high performance peripheral to share bus time of
the single AHB bus. ARM has also proposed use of a second bus
for isolation and using a single arbiter. This proposal still
allows only one transaction to progress at a given time
period.
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SUMMARY OF THE INVENTION

The immediate grant bus arbiter of this invention is a
part in the implementation of a multiple transaction bus
system. This is used in an extension of the AHB bus of ARM.
15   The bus bridge provides a means to connect two separate AHB-
style busses together and secure data integrity. Since these
busses have different characteristics, one for CPU support and
the other for support of a large amount of data transfer by a
single peripheral, the bus bridge is defined with clear
20   master-slave protocol. The bus bridge normally involves the
use of two arbiters. The arbiter on the primary bus needs to
operate differently from the arbiter on the secondary bus due
to real system time constraints.

This invention defines a bus arbiter that allows for a
25   dominant bus master to receive an immediate grant of control
on a generic AHB bus. This immediate grant bus arbiter never
relinquishes the bus if another lower priority master makes a
bus request. This makes predictable real time data transfer
possible.
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BRIEF DESCRIPTION OF THE DRAWINGS

These and other aspects of this invention are illustrated in the drawings, in which:

Figure 1 illustrates the block diagram of a prior art
5   advanced micro-controller bus architecture AMBA having a conventional AHB bus system;

Figure 2 illustrates the block diagram of an enhanced advanced micro-controller bus architecture having the multiple transaction two AHB-style bus system of this invention with
10 two arbitrators;

Figure 3 illustrates the high data transfer bus arbitration function with immediate grant bus arbiter; and

Figure 4 illustrates arbitration control logic illustrated in Figure 3.

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DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The multiple transaction advanced high performance bus system (MTAHB) of this invention is used as an upgrade to the micro-controller bus architecture AMBA of Advanced RISC
20 Machines Ltd. (ARM). The AMBA machines use RISC processors which are identified by the name ARM processors. Advanced RISC Machines Ltd. (Cambridge, U.K.) has been awarded U.S. Patent 5,740,461, dated April 14, 1998 in which this class of machines is fully described. The techniques used in this
25 invention are of wider applicability, as will be shown, and can be used in a variety of multi-processor systems having multiple bus architectures.

Figure 1 illustrates the AMBA standard. The AMBA has two main busses, an advanced high performance bus (AHB) 100 and an
30 advanced peripheral bus (APB) 120 of more moderate

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performance. AHB bus 100 is the main memory bus and couples to CPU 101 via CPU advanced high performance memory bus interface 106 to random access memory (RAM) 107, read-only memory (ROM) 108 and an external memory interface (EMI)

5   controller 102. Figure 1 further illustrates a second master device direct memory access (DMA) unit 103 also coupled to AHB bus 100. Arbitration for bus access between the two masters, CPU 101 and DMA 103, takes place in M-bus arbiter 110. M-bus arbiter 110 controls access to the various slave devices via

10   M-bus decoder 111 and select lines 112. In this basic system definition, if a high performance peripheral is required that will transfer large amounts of data, this peripheral is also placed on the high performance AHB bus 100. Figure 1 illustrates such a high performance peripheral device 130.

15   Placing this high performance peripheral device 130 on AHB bus 100 decreases system performance, because CPU 101 and DMA 103 cannot have access to memory when high performance peripheral device 130 has control of AHB bus 100. ARM has proposed an efficient arbitration scheme and split transfers to allow the

20   CPU 101, DMA 103 and the high performance peripheral 130 to share bus time of the single AHB bus 100.

ARM has also proposed use of a second bus for isolation and using a single arbiter. As shown in Figure 1, this second bus is called the advanced peripheral bus (APB) 120. APB bus

25   120 operates in the same fashion as AHB bus 100. APB bus 120 is connected to AHB bus 100 via an AHB-to-APB bus bridge 109. AHB-to-APB bus bridge 109 is a slave to AHB bus 100. The two bus system with single M-bus arbiter 110 is of limited usefulness, because it allows only one transaction to progress

30   at a given time period. Note that all high performance

devices including memory and high performance peripheral device 130 are on AHB bus 100. All peripheral devices of moderate performance including UART 115, timer 116, keypad 117 as well as peripherals 121 to 123 reside on the peripheral bus

5   120.

Figure 2 illustrates the multiple transaction advanced high performance bus system (MTAHB) used in this invention. The MTAHB uses two AHB-style buses: AHB bus 200 retained as a memory bus; and HTB bus 230 provided for high data transfer

10   bus. AHB bus 200 has AHB bus arbiter/decoder 214 and HTB bus 230 has HTB bus arbiter/decoder 216. Communication between AHB bus 200 and HTB bus 230 takes place via AHB-to-HTB bus bridge 215. AHB-to-HTB bus bridge 215 provides more than just isolation between AHB bus 200 and HTB bus 230. AHB-to-HTB bus

15   bridge 215 also allows for efficient communication between the two high performance busses. In this respect, MTAHB provides three main features:

1. a write buffer to reduce the number of stalls to the CPU 210 while writing to HTB bus 215;

20   2. a time-out counter allowing CPU 201 to change tasks if a read of HTB bus 230 takes too long; and

3. a set of control registers and control logic as required in bus-master devices.

The AHB bus 200 should contain as slaves only the blocks

25   closely related to memory as well as AHB-to-APB bus bridge 209 to APB bus 220 and AHB-to-HTB bus bridge 215 to HTB bus 230. Note that APB bus 220 connects to moderate performance peripherals 221 to 222 in the same manner as illustrated in Figure 1. HTB bus 230 contains bus slave peripherals 231 and

30   232, bus master peripheral 233 and RAM 235. HTB bus 230

supports only two bus masters, high priority data transfer bus
master peripheral 233 and AHB-to-HTB bus bridge 215. If more
bus masters are required, another HTB bus can be added to the
system through the use of another AHB-to-HTB bus bridge,
5   connected as a slave on AHB bus 200.

In the preferred embodiment the immediate grant bus
arbiter of this invention is used with the multiple
transaction advanced micro-controller bus architecture MTAHB.
The immediate grant bus arbiter technique is of wide
10 applicability, as will be shown, and can be used in a variety
of multi-processor systems having multiple bus architectures.

The AMBA specification does not define AHB bus
arbitration techniques. This was clear intention of the
specification in that there is benefit to having the freedom
15 to adopt a range of possibilities. One conventional technique
for arbitration is to use a round-robin scheme. This grants
control of the bus to one master at a time going from the
first to the last and back to the first, but with no
prevailing priority. Another technique is to give priority to
20 the last used master when there is an idle condition. This is
based on the concept that a process is occurring but has
slowed or idled for some reason and the last working master
will probably need the bus next. Finally, conventional
techniques for arbitration could be a specifically defined
25 random process.

Figure 3 illustrates an immediate grant bus arbiter 300
in a preferred embodiment used to insure the control of the
bus to the dominant master immediately upon request. The
preferred embodiment example employs the round-robin type of
30 arbiter and uses four masters, one of which is dominant. The

immediate grant bus arbiter 300 includes two major blocks, arbitration control logic 309 and state machine 310. Figure 4 illustrates details of the arbitration control logic 309. This arbitration control logic 309 contains grant logic blocks

5   341, 342, 343, and 344, one for each bus master 351, 352, 353, and 354 respectively. Bus Master A 351 is the dominant master. Each bus master 351, 352, 353 and 354 interfaces to the immediate grant bus arbiter 300 first through respective HRequest signals 301, 302, 303, and 304. State machine 310

10   successively selects each master in order (round-robin scheme) and delivers HSelect signals 331, 332, 333, and 334 to the respective HGrantA logic 341, HGrantB logic 342, HGrantC logic 343 and HGrantD logic 344 (Figure 4).

     Assume first that no bus masters are actively controlling

15   the bus. If any single bus master X issues a bus request by activating its corresponding HRequest signal 301, 302, 303 or 304, then this request will be acted upon when the corresponding HSelect signal 321, 322, 323 and 324 becomes active in its turn in the order of round-robin counter states.

20   If a non-dominant master, represented in Figure 3 by Bus Master C 353, for example, makes a request for bus control, the signal HRequestC 303 goes active. If another bus master D 354, for example, already has control, its HLockD signal 314 is active inhibiting the counter from cycling to the state

25   which will serve bus master C 353.

     If no other transfer processes are active involving other masters, state machine 310 will cycle through its states and return to apply an active HSelectC 333 to HGrantC Logic 343. The HGrantC signal 323 then goes active. This causes bus

30   master C 353 to return an active HLockC signal 313 to the

counter control logic 348 (Figure 4), signifying that bus master C 353 has control of the bus. At this point bus master C 353 will release HRequest C signal 303 to an inactive state. The HGrantC signal 323 will remain active until the transfer

5   is complete. Counter control logic 348 acts upon the active HLockC signal 313 applying an inhibit signal to the counter-decoder block 349, inhibiting counter action and freezing HSelect signals 332, 333 and 334. When bus master C 353 completes its data transfer processes, it allows HLockC signal

10   313 to go inactive. Counter control logic 348 no longer inhibits counter-decoder block 349 which resumes round-robin action. Counter interface 347 allows HGrantC signal 323 to go inactive. This readies immediate grant bus arbiter 300 for another bus grant.

15   Suppose the dominant master, in this example bus master A 351, makes a request for bus control by assertion of HREQUESTA signal 301. HREQUESTA signal 301 is routed to HGrantA logic 341 in the normal fashion. HREQUESTA signal 301 is also routed to HGrantB logic 342, HGrantC logic 343 and

20   HGrantD logic 344 inhibiting possible bus control from being passed to bus masters B 352, bus master C 353 or bus master D 354 even if state machine 310 has selected one of them based on the round robin algorithm.

         If a non-dominant bus master already has control of HTB

25   bus 230, the occurrence of HREQUESTA signal 301 at the corresponding HGrantB logic 342, HGrantC logic 343 or HGrantC logic 344 will initiate a hold on that control. Non-dominant bus masters 352, 353 and 354 served by grant immediate bus arbiter 300 are configured to suspend transfer action and

30   store status of the suspension until control can be restored

through normal HRequest signaling.   State machine 310, acting
upon the immediate grant request of dominant bus master A 351,
will cycle through its states and in turn will apply an active
HSelectA signal 331 to HGrantA logic 341.   HGrantA signal 321
5   then goes active causing dominant bus master A 351 to return
HLockA signal 311 to counter control logic 348.   This signals
that bus master A 351 has taken control of HTB bus 230.
Counter control logic 348 applies appropriate control to the
counter-decoder block 349, inhibiting counter action and
10   freezing the HSelect signals.   Upon completion of dominant bus
master A 351 data transfer, HLockA signal 321 goes inactive
and round-robin action resumes.

In a real-time application, where the events that trigger
an HTB bus peripheral occur externally to CPU 201, a priority
15   scheme must be created that will insure the speedy transfer of
data from the HTB bus peripheral to its destination, which may
be another peripheral or memory.   Due to the non-deterministic
behavior inherent to generic AHB bus arbitration, HTB bus
arbiter/decoder 216 will always grant HTB bus 230 to the
20   peripheral on the highest channel.   In this example that is
dominant bus master A 351.   Even if AHB-to-HTB bus bridge 215
has control of HTB bus 230, if dominant bus master A 351
requests control, them HTB bus arbiter/decoder 216 will
suspend the current AHB-to-HTB operation and grant control to
25   dominant bus master A 351.   AHB-to-HTB bus bridge 215 will
handle the stall operations during a write in a write buffer
or from a read by initiating a time-out counter.

Referring to Figure 2, there will normally be only two
possible masters on HTB bus 230: one dominant bus master 233
30   and AHB-to-HTB bus bridge 215.   The dominant bus master 233

will occupy a higher priority, while AHB-to-HTB bus bridge 215 occupies the lower.

What is important is that, for real-time situations, normally it is necessary to give a single master super priority, so that it can never lose arbitration. This HTB bus master is the dominant HTB bus master (DHTBM). If DHTBM controls the bus at a given time, it will never lose it until it is finished with its data transfer and all other processes wait. If DHTBM requests the bus, it is given immediate control, forcing AHB-to-HTB bus bridge 216 to suspend processes. There are some real-time constraints with some modules. Thus allowing inherent non-deterministic bus arbitration to be the only rule would have a negative overall impact on real-time systems.